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ABSTRACT

The domain-referenced approach to assessment results in a set of tests that are closely linked to theoretical propositions about aspects of reading comprehension. In this paper, the definition, validation, and use of domains are described, and one strategy for developing domain-referenced measures is proposed. The strategy involves identifying a plausible candidate domain, identifying prototypic items from that domain, specifying relevant variables thought to affect the difficulty of responding correctly to those items, creating sample items, and verifying the domain empirically. An attempt was made to implement this strategy in measuring "ability to find the main point of a passage." In general, the strategy seems to be a useful approach to test development and theory refinement, in that it effectively samples and screens variables affecting performance in the domain. On the basis of this study, suggestions are made for further research on finding the main point, and appropriate next steps in developing domain-referenced measures are proposed. (Author)

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CENTER FOR THE STUDY OF READING

Technical Report No. 86

DEVELOPMENT AND TRIAL OF A MODEL FOR DEVELOPING DOMAIN REFERENCED TESTS OF READING COMPREHENSION

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Development and Trial of a Model for Developing Domain Referenced Tests of Reading Comprehension

Introduction

There are at least three approaches to constructing tests of reading comprehension. The table-of-specifications approach used for most standardized achievement tests results in general measures of achievement based on performance over a broad range of content areas and tasks. The objectives-referenced approach results in a set of discrete items, each keyed to a specific instructional objective. The domain-referenced approach results in a set of tests which are derived from and which feed into a theoretical proposition about some aspect of reading comprehension.

Because of their generality, tests derived using the first approach are of limited value for helping practitioners make decisions about instructional sequences or strategies. Their generality also results in their having little value as outcome measures in research on comprehension processes.

Because of their specificity, tests derived using the second approach permit rather precise determination of whether pupils have attained particular objectives, but are of little value for assessing pupils' acquisition of more broadly-conceived skills or strategies for comprehending written discourse. That same specificity severely limits their utility as outcome measures for research on comprehension processes.

Additionally, both the table-of-specifications and the objectives-referenced approaches are only remotely connected to theoretical models

of reading comprehension. This lack of a validated theoretical base further limits their utility.

In this report, an argument is presented for the potential value of the domain-referenced approach. The report proceeds from an initial definition of domains through a discussion of the validation and potential utility of domains. It then presents one test-development strategy and describes the development, administration, and analysis of a tentative measure. (In this pilot effort, only a one-item "test" was developed.) Finally, the feasibility of the approach is discussed and some suggestions concerning the future roles of domain-referenced measures are presented.

Defining, Validating, and Using "Domains"

Definition

In the context of this report, a domain is a well-defined set of items. There are at least three ways to define a set of items: (1) in the most primitive sense, by simply enumerating all the constituent items; (2) in the most elaborate and comprehensive sense, by stating the complete set of rules necessary to generate items in the domain--rules which can be followed by a computer or a clerk; and (3) in the sense that is most likely to be useful for domains representing complex behaviors, by stating the rules that a judge may apply in separating instances from noninstances of the domain, as they occur in nature.

Arriving at a complete specification of a domain involves both identifying the domain and creating or collecting assessment items for the domain. Since it is unreasonable to presume that all the relevant constraints and complexities characterizing a domain can be prespecified,

defining domains is an interactive process involving the interplay of conceptualization and empiricism (theory and observation). It is in the process of translating verbal labels (e.g., "finding the main point of a passage" or "recognizing cause-and-effect relationships") into measurement tasks that necessary constraints on the definition are identified and the subtleties and complexities of the domain are elucidated (Hively, 1975).

In attempting to define a domain, one usually begins with a collection of exemplary or prototype items: important things that learners do in the area of interest. Then, a sampling space of comparable or related items is generated by transforming and generalizing the prototype items and by deducing other related items from a theoretical analysis of the process required to obtain correct answers.

Transformations and generalizations of the items are often obtained through the development of "item forms" in which components of an item are allowed to vary over a specified range of possibilities. Lists of replacements for the variable components are prepared so that new items may be generated by selecting from these lists new values for the variables. For example, compare passage "A" and passage "I" which appear in the Appendix of this report. Both are identical with the exception of the first paragraph, a "component of an item," which is "allowed to vary" from a paragraph that directly states the passage's main point (as in passage "A") to a paragraph that indirectly states the passage's main point (as in passage "I"). New items may be generated by varying other passage components in addition to the first paragraph.

Other related items may be generated by analyzing hypothetical teaching sequences that would help learners acquire the skills necessary to respond correctly to the prototype items. Processing models of a learner's behavior may also lead to the identification of related items which the learner would have to answer correctly if he or she performed according to the model. Such models--at various levels of elaboration--may also be used to generate predictions about variables affecting the difficulty of items. Specifying different values of these variables allows one to generate different classes of items in the domain.

Typically, then, a domain consists of a set of items partitioned into subsets according to some theory. The domain, together with the theory that rationalizes it, often redefines the area of original interest.

Validation

Given a skill or behavior and its associated items and theoretical framework, the next step is to administer the items to a group of examinees and to use their performance as a basis for validating and possibly redefining the domain.

How are domains validated? The question is not simple to answer because each of the several types of validation requires unique procedures. What follows is a description of four types of domain validation, along with a brief consideration of the crucial issues relating to the problem of validating domain-referenced tests.

The first type is internal construct validity. Following this approach, the theory that defines and partitions the domain may be used to predict the behavior of learners in several ways:

(1) It may be used to predict the relative difficulty of items over some population of learners.

(2) It may be used to predict patterns or scalar relationships among correct and incorrect answers to items, perhaps representative of underlying strategies used by individuals or subgroups of learners.

(3) It may be used to predict generalization of difficulty relationships or patterns of correct and incorrect answers to other samples from the subdomains, i.e., partitions of the larger domain. To elaborate: If one draws one or two items from each subdomain of a larger domain and has a theory that predicts which ones of those items an individual will answer correctly (and the data support the theory), then the generality of the findings needs to be clinched by drawing other comparable items from the same subdomains and seeing whether the same relationships hold. Findings must be replicated with some degree of reliability across independently sampled test forms. A single test is a trivial domain.

(4) The theory may be used to predict transfer and generalization among subsets in the domain for learners who are being taught new skills defined by those subsets. This is probably the strongest way to validate a domain, and it should also be elaborated.

In the first three instances above, no teaching took place. The domain was validated simply by looking for relatively stable and theoretically interpretable patterns of performance from individuals or groups encountering the items for the first time. One can go beyond this to diagnose the pattern of an individual's initial performance, teach him or her to respond correctly to some previously unknown set of items, and

then look for theoretically predictable changes in performance in related subdomains.

The second type of domain validation is external construct validation. The theory that defines and partitions the domain may be used to predict a learner's behavior on previously uncatalogued items. For example, if a learner's behavior has been diagnosed with respect to the domain of "finding the main point," a teacher might bring a new passage from the Reader's Digest and ask the examiner to predict whether the learner could correctly state its main idea. The tester could then apply the theory which has been used to structure the domain and come up with a probability statement about the learner's chances of success.

The third type is external predictive validity. The theory which defines and partitions the domain may be used to predict judged performance in related real-world tasks. For example, can a student who does a good job in the domain of "finding the main point" perform effectively in a reading discussion group?

External predictive validity may be either correlational or experimental. In the correlational case, one finds people who do well and people who do poorly on the domain and looks at their related behavior in the discussion group. In the experimental case, one finds people who do poorly on the domain and poorly in the discussion group, then teaches them to perform well in the domain to see if there is any change in their performance in the discussion group.

The last type of validation is face validity. Judges simply rate the extent to which the items truly reflect the skill being assessed.

Technically speaking, it is not necessary for a domain to have face validity, but if it doesn't (a "cloze" domain might be an example) then its internal construct validation may be of very little interest. Justification of the domain's existence for practical purposes would then have to depend on external predictive validation. And, if its external predictive validity is good (the "cloze" test may again be an example), then that would seem to suggest a need for some intensive analysis to tease out the actual basis for the correlations.

Use

Domains have both theoretical and practical applications. In terms of theory, a domain serves as a concrete space for experimentation which operationally defines an area of generalizability for experimental results. It allows one to make precise statements about generalization and transfer and about relative difficulty among the items. However, the main use of domains is likely to be a practical one: as targets for instructional interventions. If one has a well defined domain, one can observe learners acquiring it, try a variety of teaching and curriculum techniques, and--given an elaborated set of items representing the domain--closely monitor the efficiency and effectiveness of instructional procedures.

A Development Strategy

One strategy for developing domain-referenced measures is as follows: (1) identify a plausible candidate domain, (2) identify prototypic items from that domain, (3) specify relevant variables thought to affect the difficulty of responding correctly to those items, (4) create sample items,

and (5) verify the domain empirically. As employed in this study, this strategy emphasizes the internal construct validation of a domain-referenced measure, using the first of the four approaches described earlier.

Ideally, a theory of behavior will guide the choice of candidate domains. The needs of both researchers and practitioners in the field will determine the necessity to measure particular performance domains. Under such circumstances, the research base itself will provide an adequate set of initial specifications for the domain. Unfortunately, knowledge about components of reading comprehension in the transitional stage (grades 4 through 8, the focus of the Center for the Study of Reading) falls far short of qualifying as a basis for "theory." Thus, it was necessary to use another strategy (described in the next section of this report) to identify a candidate domain for our initial effort.

Following the identification of a candidate domain, prototypic items for assessing behavior in that domain are located or produced. Some ways of coming up with such prototypic items are looking at existing tests, observing instructional sequences, analyzing learner behaviors, and/or studying instructional materials. Essentially, the task is to come up with stimulus situations that seem likely to evoke responses demonstrating the presence or absence of the behavior(s) exemplifying the target domain.

The next phase (steps 3-5 above) encompasses the development which typically takes place in any experimental study: variables and techniques are generated from available theories. The choice of particular experimental variables is based upon theoretical predictions about their relative

processing demands (e.g., manipulations of syllabic structure is expected to vary the load placed upon a decoding process in making lexical identifications). Failure to find performance differences for different levels of a variable then indicates that the theoretical surmises were incorrect, and that revisions of the theoretical model are required. Once these variables have been identified, items are constructed or collected which differ systematically along the specified variables while other variables are held at a constant level. The items should be at least partially ordered in difficulty on the basis of the theory used to generate them. That is, one would generally expect items that are easy on all the variables affecting the behavior to be easiest, items that are easy on all but one of the variables affecting the skill to be next easiest, and so on.

Empirical verification may be carried out in at least two different ways: (1) a rating procedure by expert judges, and (2) a collection of performance data from learners. Although the rating procedure was not employed in the study described later, a description of both techniques is presented.

In the rating procedure, ratings are obtained of item difficulties with respect to the skill domain from an independent group of raters. Scaling techniques are used that will reveal inconsistency in judgment both within a rater and from rater to rater. If rated item difficulties do not correspond to predicted item difficulties, reasons for disagreement should be analyzed and a revised theory developed that specifies how much impact particular variables have on item difficulty. Additional items are then either constructed or selected following the revised set of principles.

Ratings are again obtained, and the iterative procedure is continued until a set of rules for item construction has been specified that can be followed by item writers and that yields items that vary systematically with respect to the specified variables while not varying along irrelevant dimensions. Each of these requirements will have been met when independent raters affirm these claimed properties for the items. In other words, a satisfactory set of rules for item construction exists only when it is possible to predict, based on those rules and the variables derived from the associated theory, the rated difficulty of the resulting items.

On each iteration of this procedure of theory specification and revision, item selection or construction and modification, and evaluation by independent raters, decisions have to be made about particular items. If an item is not transitively related to other items in rated difficulty, it should be eliminated and a principle written down which will serve to avoid the construction or selection of similar items in the future. This amounts to refining the definition of the domain. In other cases, items might be scalable but show substantial variability in scale position for different raters; such items should be retained, but modified in order to increase their scalability. The principles used in modifying items should be explicitly stated, so that they can be incorporated in the specifications used for generating additional items. Finally, if a number of item variables are being employed in the construction or selection of test items, it is possible that subsets of items which represent a single variable may have poor scalability. In such cases, decisions should be made

about whether or not to continue to use this relevant item variable as a means for manipulating difficulty within the specified skill domain.

The second way to validate empirically is to collect performance data from learners. Items are presented to a sample pupil population and performance data are obtained for each item. The validity of the items can then, in part, be established by showing that the variables selected for study are predictive of item difficulty. This technique was implemented in the study described later.

Since a domain-referenced test assigns test scores on the basis of an item difficulty metric, the statistical (test theory) models used to represent subjects' performance within the specified skill domain should provide scale values (item difficulty parameters) for the individual items and a test score that shares the metric associated with the items. If these requirements are met, then subjects can be assigned test scores which represent the level of item difficulty at which they can successfully perform.

Three test theory models are suitable for this purpose: the Guttman Model, the Rasch Model, and the Logistic or (equivalently) Normal-Ogive Model (see Lord & Novick, 1968). These models all have the property that scale values are associated with the individual items, and subjects' test scores represent positions on the item-difficulty scale. Thus, if the item difficulties are closely predictable from the final theory specification and correspond to the rated difficulties, one has a test whose scores are domain-referenced and do not require norming in order to provide metric information about the processing domain of interest. Each of the test

theory models mentioned above will yield a set of item parameter estimates that can be compared with predicted difficulties obtained whenever the rating procedure is used. If the correlation (perhaps the rank correlation) between actual item difficulties and predicted difficulties is high, the test's validity (and that of the theory as currently specified) is, at least partially, established. If empirical difficulties are found to be unrelated to predicted difficulties, then the test cannot be said to measure the skill domain for which it was constructed. Given a close correspondence between predicted item difficulties and the obtained difficulty parameters, one would have a test with defensible scale properties and high internal construct validity.

An Application of the Strategy

The remainder of this paper describes one attempt to apply procedures outlined above to one aspect of reading comprehension. Because of the lack of a good theory of reading comprehension, we began by reviewing various taxonomies, curriculum packages, and reading tests in order to locate a plausible "candidate domain." The choice--finding the main point (FMP) of a passage--appears (1) in most taxonomies of reading comprehension, (2) as an explicitly-taught skill in several sets of reading curriculum materials, and (3) as one of the skills to be assessed in virtually every standardized test of reading comprehension.

Having identified this behavior as a possible domain, an attempt was made to locate prototypic items requiring respondents to exhibit the behavior. More than 20 question types were discovered (e.g., "A good title

for the passage is ...," "This passage mainly tells ...," "The main idea is ...," "The author's purpose in writing the passage was ...," "The topic of this story is ..."). Almost every type was in the form of a multiple choice item so that examinees had to select the "best" response from among the four or five alternatives given. In contrast, we chose to ask examinees to complete the statement, "The story mainly tells ...."

A few trial passages were identified to administer to a small number of readers. It was found that the question we were asking, and "main point" questions generally, were inappropriate for certain kinds of passages (e.g., travelogues), so the definition of the domain was narrowed by specifying not only question type but also general passage characteristics. The set of constraints on passages required that they be expository and have a single main point. Further, they should contain relatively novel, but politically and emotionally neutral, content, and at least appear to be non-fiction.

Method

To try out the strategy for validating a domain, we compiled a set of experimental materials, developed procedures for using those materials, administered the materials to a sample of examinees, and analyzed the results.

Materials

Vocabulary test. In the development of experimental materials (passages), an attempt was made to keep the vocabulary simple so that subjects with low vocabulary levels would not have difficulty finding

the main point for this reason. In an attempt to protect against the possibility that some examinees might have an inadequate vocabulary for the task, 20 even-numbered items (i.e., items 10, 12, ..., 48) from the Gates-MacGinitie Reading Test,[1] Survey D, Form 2 were administered to the students.

Items. Following the selection of FMP as our prototype domain, variables considered to affect the performance of individuals at the task of FMP were identified. Table 1 presents a list of twelve variables (each variable representing a characteristic of a passage associated with the task of FMP) that was compiled by consulting relevant literature and colleagues. Only four variables were selected for manipulation in our generation of the passages to be incorporated into test items. A brief discussion of each of those four variables follows.

Insert Table 1 about here

A few preliminary investigations led to the identification of the variable entitled "fit of passage structure to model reading strategy." We found that many sophisticated readers (college graduates) have a preferred strategy for finding the main point of passages. These readers typically read the initial one or two paragraphs rather carefully, continued by reading the final paragraph or two, and then jumped to the middle paragraphs to read the first sentence of each. We thus anticipated that if a passage was structured such that main point statements appeared in "expected places" (as operationally defined by the reading

strategy described above), readers would find the main point more easily than if information about the main point appeared in "unexpected places."

A second variable selected for manipulation involves how a passage's main point is stated. We anticipated that if the author of a passage stated its main point in a clear and direct manner, readers would find the main point more easily than in the case of an indirect statement. Of the several ways to state main points indirectly, we chose either (1) to present examples and facts to portray a passage's main point, or (2) to provide an analogy to suggest a passage's main point.

The frequency of main point statements in a passage is the third variable. A high frequency condition had three main point statements and a low frequency condition had one. It was hypothesized that the high frequency condition would facilitate performance.

The final variable selected for manipulation was the amount of information in the passage that did not directly support the main point. Such information includes ideas which are tangential and/or irrelevant to the main point or its development. In some passages virtually all ideas supported the main point; in the other passages, various sentences and clauses were incorporated which did relate to passage content but did not lend support to the main point. This latter condition was hypothesized to make finding the main point more difficult.

A set of items was constructed which had these components: (1) the directions, "Please read this story and try to find out what it is mainly about," (2) a passage, and (3) directions to complete the following sentence, "The story mainly tells...." Item passages were generated by

systematically manipulating the four variables just described while holding all other variables at a constant level. The contents of the item passages were based on materials found in "Dimensions in Reading--Manpower and Natural Resources" (Science Research Associates, 1966).

Three versions of a passage were generated for use as practice items. Each had the following main point: "Bald eagles are being killed, possibly to extinction." The variable classification employed in these three versions are presented in Table 2. With respect to the anticipated difficulty

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Insert Table 2 about here

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of these passages, version one was predicted to be the easiest, version two was considered moderately difficult, and version three was considered the most difficult. Each passage consisted of approximately 350 words, and each had roughly a sixth grade readability level as determined by the SMOG readability formula (McLaughlin, 1969) in combination with "A Living Word Vocabulary: The Words We Know" (Dale & O'Rourke, 1976). A copy of each practice item can be found in the Appendix.

Sixteen versions of a passage were generated for use as experimental items. Each had the following main point: "Building the Mackinac Bridge was a difficult job." The sixteen versions of the passage represented all possible combinations of the four manipulated variables. Each passage consisted of approximately 600 words. Each had roughly a sixth grade readability level as again determined by the SMOG readability formula (McLaughlin, 1969) in combination with "A Living Word Vocabulary: The

Words We Know" (Dale & O'Rourke, 1976). A copy of each experimental item can be found in the Appendix.

Questions about experimental passage details. In addition to items about the main point of the passage, four questions were designed to assess students' knowledge of certain details about the passage. Two of the four questions assessed ideas not directly in support of the main point, while two others assessed supportive ideas.

Test Booklet Administration

Test booklets consisting of the vocabulary test, a practice item, feedback from the practice item (presenting three possible "acceptable" responses), and experimental item, and the four questions about experimental passage details were administered to students by test monitors in a classroom setting. The students were allowed six minutes to complete the vocabulary test, thirty minutes to complete the practice and experimental items, and ten minutes to respond to the detail questions. The design of the test booklets did not allow students to refer back to the experimental passage while responding to the four detail questions.

Subjects

Subjects were 46 sixth graders and 46 eighth graders from two local schools. There were 56 males and 36 females in the sample. The sixth graders were from a progressive elementary school in the community, while the eighth graders were from a much larger junior high school.

Design

The data analysis scheme was basically a factorial analysis of covariance with vocabulary scores used as a covariate.[2] The five factors in the complete factorial were the four passage characteristics (detailed in the materials section) and the difficulty level of the practice passage. This gave a $2^4 \times 3$ layout, with two subjects per cell (except for four cells in which there were one subject each. The use of vocabulary scores made it unnecessary to include grade level as a factor in the design. The estimate of error was generated by pooling the fourth and fifth order interactions with the within-cell variation. Primary dependent measures were: (1) a measure of total score on finding the main point, (2) a score on accuracy of the topic, action, and modifier of the main point, and (3) number of correct responses to the four detail questions. Except for measures about detail questions, all measures were determined on both the practice and experimental passages.

Response Scoring Rules

All main point statements were scored by rules. Three categories (topic, action, and modifier) were used for each statement, and each category could be assigned a score of 0, 1, or 2, depending on the accuracy of the student's response. A response received 2 points if it was exactly correct, 1 point if it was correct but either too general or too specific, or 0 points if the response was incorrect or absent. In addition, 1 point could be subtracted from any category if irrelevant or extraneous information was included with some correct information. Further, 1 point was

subtracted from the total score (the sum of topic, action, and modifier scores) if additional information was included that could not be identified as applying to any one of the specific categories; however, this point was not subtracted if the total score was 0. Thus, each category score could range from 0 to 2, producing a total score ranging from 0 to 6.

The following should clarify the application of the scoring rules. A correct statement of the main point for the experimental passage is "Big Mac (topic) was built (action) with great difficulty (modifier)." Regarding the topic only, "Big Mac" (or any response clearly identifying that particular bridge, such as, "The bridge over the Straits of Mackinac") is exactly the correct response and would receive 2 points. A response like, "The bridge" or "Bridges" would be too general, and one like, "The towers on Big Mac" would be considered too specific; such responses would receive 1 point. Responses which failed to mention the bridge or which mentioned the wrong topic received 0 points. If the topic had been awarded 1 or 2 points and had included extraneous information, then 1 point would be subtracted. For example, "Big Mac and the highway leading to it" would receive a score of 2-1=1 for its topic score.

There were 184 responses altogether--92 from experimental and 92 from practice passages. Responses were scored by five independent raters. If there was any question regarding the scoring of a response, it was reviewed by all five members and the score was determined by consensus of the entire group.

To obtain a measure of the reliability of the scoring procedure as it was applied to the students' experimental responses, the following

procedure was employed: One half of the 92 responses from experimental passages were randomly selected to be rated by another group of five independent raters. These raters were given (1) written instructions about the rules for scoring the responses, (2) an example passage, and (3) the 46 randomly selected responses. Each rater individually scored all 46 responses, then all met as a group to review each response in order to arrive at a group consensus. These scores (both individual scores and group consensus scores) were then correlated with the scores awarded by the initial raters.

Results

Reliability of Scoring Procedures

Consensus of total scores for 46 randomly selected experimental items as determined by the initial group of raters were highly correlated with the consensus of total scores for the same items as determined by the second group of raters, r = .92. Total scores assigned by each of the five raters of the second group were also highly correlated with consensus of total scores of the initial group of raters, r's = .94, .93, .93, .85, .85.

Total Score Analysis

Table 3 presents means and standard deviations for the covariate (vocabulary) and scores for "main-point" statements from both practice and experimental passages.

Insert Table 3 about here

In an ANCOVA design, the main effects, first order interactions, second order interactions, and third order interactions were determined using the pooled higher order terms as an estimate of error (as had been planned a priori). The vocabulary score was used as a covariate, with the four experimental passage conditions and the practice passage condition as the five independent variables. The total experimental passage score was the dependent variable. The covariate had a correlation of .45 with total score.

The main effects for "fit to strategy" and "direct/indirect" appeared to be reliably different from zero ($F = 6.39$, $df = 1,54$, $p < .02$ for "fit to strategy"; $F = 6.22$, $df = 1,54$, $p < .02$ for "direct/indirect"). A good "fit to strategy" and a direct main point statement made the task of finding the main point easier. None of the other variables reliably affected the dependent variable.

Since the practice passage variable had been included only to deal with what was perceived to be a nuisance factor, the data were collapsed across it and reanalyzed using a four-factor ANCOVA (as had been planned). The reanalysis led to exactly the same conclusions, with significant main effects for "fit to strategy" ($F = 6.30$; $df = 1,75$; $p < .02$) and "direct/indirect" ($F = 5.31$; $df = 1,75$; $p < .03$). Computation of an omega squared statistic for these two factors indicated that "fit to strategy" accounted for approximately 6% of the variance in finding the main point, while "direct/indirect" accounted for 5%.

Subsidiary Analyses

Additional analyses were performed using the same four-factor ANCOVA as described above, except that three other dependent variables were used--the part scores on topic, action, and modifier. For these analyses the action and modifier variables were recoded so that 0 remained 0, while 1 and 2 became 1; this was done to correct the U-shaped distribution of these measures. As expected, the multivariate test indicated that "fit to strategy" and "direct/indirect" were the only two reliable effects ($p < .02$). The "fit to strategy" variable affected the action and modifier measures, but it did not affect the topic measure ($p < .02$, $p < .01$ and $p < .73$, respectively). In contrast, the "direct/indirect" variable significantly affected the topic measure, but it did not affect the action or the modifier ($p < .001$, $p < .93$, $p < .72$).

The ANCOVA design again was used to analyze the scores on the four detail questions. Since the analysis showed that there was no main effect due to the practice passage condition, a second ANCOVA with the four experimental factors was performed. This analysis showed a main effect for only "non-supporting details" ($p < .05$). Subjects who read passages with many "non-supporting" ideas did less well on the detail questions than did subjects who read passages with few non-supporting ideas. Since (1) this main effect was only marginally significant and (2) the distribution characteristics of the dependent variable were rectangular and probably violated some of the covariance assumptions, additional analyses and interpretations are not presented.

The next analysis gives some indication of the extent to which the major findings with respect to the variables might generalize across passages. Recall that each subject received a practice passage that was classified as either easy, moderate, or difficult (see Table 2). The "easy" passage had (1) three statements of the main point, (2) direct statements of the main point, (3) main point statements located in predictable places in the passage, and (4) few non-supporting details. The first and third of these characteristics were altered for the "moderate" passage while all four were altered for the "difficult" passage. Of the 16 experimental passages, three corresponded to the practice passages in terms of these characteristics. By disregarding practice passage scores of those 17 subjects who responded to these three experimental passages and by utilizing their experimental passage scores instead, it was possible to analyze performance according to the design in Table 4. Using this two-way

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Insert Table 4 about here

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classification, we performed a two-factor ANCOVA with total score as the dependent variable and vocabulary score as the covariate. The passage difficulty effect was substantial ($p < .001$) while text ($p > .99$) and the Text x Difficulty interaction ($p > .29$) were not. This result suggests that the overall effect of the four manipulated variables was consistent across texts, while the particular passage used did not affect performance. Furthermore, performance on easier passages was invariably superior to performance on more difficult passages for both texts.

Regression Analysis

A potential payoff associated with the domain referenced approach is the prediction of the difficulty of a passage for a particular person. To investigate this possibility, a regression analysis was performed in which the dependent variable was total score on FMP and the predictors were vocabulary, "fit to strategy," and "direct/indirect." Each of the latter two variables was coded 0 or 1. Since the resulting multiple correlation was .54, the three variables accounted for approximately 30% of the variance in the total scores. Vocabulary accounted for 20% of the variance, and the two passage variables each accounted for approximately 5%. The standardized regression weights were .44, .22, and .21 for the vocabulary, "fit to strategy," and "direct/indirect" predictors, respectively.

Discussion

This section begins with an evaluation of the proposed strategy for developing domain referenced tests based on the results just presented. Some possible next steps in exploring the FMP domain are considered. Finally, further explorations of the development strategy are proposed.

Evaluation of the Development Strategy

Each of the five component stages in the strategy for developing domain referenced measures is evaluated below, followed by a brief summary statement.

Domain identification. The initial step in the proposed development strategy is domain identification. Earlier, it was stated that "ideally, a theory of behavior will guide the choice of candidate domains." Indeed,

the relationship between research, measurement, and educational practice is one of symbiosis. Researchers want to measure the effects of manipulating presumably-relevant variables on certain interesting (and hopefully important) outcomes. Thus, meaningful research depends on the availability of adequate outcome measures. In this context, the outcomes to be measured are specified (perhaps incompletely, at first) by the theoretical propositions that guide the research.

Some of the outcomes important in theory-building may also be shown to be relevant to educational practice. In these instances, again, the measurement of outcomes serves as a check on the efficacy of innovative educational practice.

In both of the above contexts, the development of domain-referenced measures is served and is guided by the needs of the potential users of the measures. However, in the present study we had no potential users coming to us for help in creating a measure of a chosen domain. Instead, we were trying to anticipate the need for such measures and to create procedures for developing them. Accordingly, our choice of a domain was merely an ad hoc attempt at identifying an interesting component of reading comprehension that could be used to try out and refine our development strategy.

Under the circumstances, the selection of FMP seems to have been a fortunate one. It provided the framework for implementing the approach; it had "face validity" to those interested in studying reading comprehension; and it permitted us to work through virtually every step of the proposed strategy.

Prototypic item identification. Following the identification of a domain, the next task is to locate or generate items that seem to represent the desired behaviors. This may produce an uncomfortably diverse array of "item forms." For example, in the present study, numerous probes for FMP were encountered (e.g., "The story mainly tells...," "The best title is...," "What was the author's purpose?"). It was also discovered that main point questions could not meaningfully be asked of certain types of material (e.g., anecdotes, travelogues). Further, various kinds of main points were encountered (e.g., theme, topic, moral) which affected the utility of identified items. Thus, the review of existing measures proved useful to indicate some potentially confounding variables that might affect performance in the domain.

Specification of relevant variables. After the domain has been identified and prototypic items have been located or generated, the next step requires that relevant variables be identified which could affect performance. In the absence of a priori theoretical guides, we chose to do this by consulting the literature, curriculum packages, tests, and reading teachers. In addition, we asked students to tell us how they read to find the main point, and we observed students as they did so. Since our list soon included 12 possible variables, we feel confident that a group of knowledgeable teachers, researchers, and/or curriculum developers could quickly generate a reliable list of variables.

Operationalization of relevant variables. The next step requires that the relevant variables be operationalized. That is, activities or operations which quanitfy levels along the variable continuums need to

be specified. Problems of several types arise in this kind of activity. One problem involves a matter of preference as each of several models or research paradigms can lead individuals to prepare different operational strategies. Theoretically, their differences could lead to fundamental disagreements.

Another problem arises when the designs become crossed, i.e., when one must interpret the meaning of several definitions simultaneously. Sometimes, nonsense cells which represent non-existant "real life" conditions are produced. For example, while we wanted to use a text that has no main point statement, we could not use the condition, "frequency of main point statements equals zero." To have a zero main point condition would have negated the variable "direct/indirect statement of the main point."

The time and skill required to generate the various text conditions is another problem. Selecting and/or writing the passage content, shaping the text to conform to the operational variables, and editing the entire discourse to insure a coherent passage require skill and effort. Large scale production of domain referenced tests may not be feasible.

Collection and analysis of performance data. The final step in this study was the collection and analysis of performance data. Perhaps the most important information learned from the data was (1) the empirical verification of the operationalization of the variables chosen; (2) the potency of each variable; and (3) a description of the relationships among variables.

The results of this study showed that the experimental variables caused a small (5-6% of variance for each of the two significant variables),

but reliable ($p < .02$) difference in the performance of students on this task. How large these differences must be before they become interesting depends primarily on the decision-making paradigms in which the measures will be used. Needless to say, at present the differences are not large enough to serve any worthwhile function in decision-making. Ideally, more insight into the nature of these variables will enable them to be operationalized such that the differences will be large or to be discarded because their effects are too small to merit further consideration. In the former case, a regression technique could then be applied to predict the difficulty of an item. When this can be done, the model will have changed from a descriptive one to a predictive one.

Given that we began with very little knowledge about FMP, the results were encouraging. However, only a fraction of the needed empirical work has been done. Yet, our data collection seemed to demonstrate clearly the relative effects of the variables. The major drawback to this approach is the cost. Large amounts of subject time, experimenter time, and materials are needed.

Summary. In general, the proposed strategy seems to be a reasonable way to develop domain referenced tests. By the time a domain has been well developed, the evidence to support its psychometric properties should be ample. The only potential drawback to the strategy is the large amount of time and resources required to develop the materials (operationalize the variables) and to go through the several model building iterations.

What Would Be Done Next with the FMP Domain?

First, those variables that have not systematically affected performance would be at least temporarily eliminated, namely, "frequency of mainpoint statements" and "number of non-supporting details." They might be re-introduced at some later time to determine whether or not they have interactive effects with other variables. Second, additional important variables would be incorporated into the model. These might come from the list presented in Table 1. At any rate, the model would eventually include cognitive processing and individual difference variables. Third, a sample of other similar texts would be used so that we can determine how generalizable the technique is. To date we know that it works rather well with only two passages. Fourth, a sample of similar item formats (i.e., other than "The story mainly tells....") would be used to explore their impact on the task of FMP. And last, we would need to investigate other forms of validity of the FMP domain.

It is important to keep in mind that this was a pilot effort at applying a procedure for developing domain-referenced measures. The procedure was a rather effective one for sampling and screening variables affecting FMP and for creating what was in fact a one-item "test." A needed next step is to develop a test with multiple measures per individual, employing a series of passages for which examinees are to find the main point. It would then be possible to apply one or another of the test theory models discussed earlier in order to determine scale values for each of the items. Once this scaling was accomplished, one could obtain psychometrically defensible estimates of examinees' ability.

Suggestions for Future Development of Domain Referenced Tests

To reiterate the earlier discussion, we concluded that developing domain referenced tests is a theoretical, model building, research activity. The basic steps in the process are: (1) domain identification, (2) prototypic item identification, (3) specification of relevant variables, (4) operationalization of relevant variables, and (5) collection and analysis of performance data. Depending on the way the variables behave, steps 3 through 5 are repeated until performance on domain items is predictable and a good metric can be determined.

With respect to further refinement of a domain, a two-pronged attack seems called for. Validation of the theory upon which a domain is based is intrinsic to our approach to test construction. Empirical validation of a domain reveals which variables make a difference. However, the theory also can be enriched from related research. (For instance, the difficulty of finding the main point no doubt depends upon the inferential demands of a passage. Eventually, variables reflecting this characteristic should be included in the definitions of the FMP domain.) A point to be emphasized, though, is that the development of domain referenced tests must proceed in parallel with other research. Because of the ability of domain referenced tests to measure an individual's performance with respect to the domain being investigated, it would be unwise to wait until linguists and psychologists believe they have a comprehensive model of discourse structure and processing. Domain referenced tests could be quite useful to researchers developing such a model.

In which additional domains should prototype test research be done? Research on the cognitive processes involved in reading with comprehension is revealing potentially important domains. Examples include drawing pragmatic inferences, detecting failures in comprehension, and taking steps to overcome failures in comprehension. The current state of the art in reading education is also a source of ideas about significant domains.

Now that a case has been made for a rational set of procedures for the development and validation of domain-referenced tests, are the resulting products of any use? The theoretical and practical applications mentioned earlier appear to be relatively straightforward. However, currently implementing domain referenced tests in practical settings may pose some difficulty. For domain referenced tests of the type we have been discussing to be effectively utilized in schools, there may have to be some changes in typical classroom procedures and in conventional ideas about how tests are used in the ongoing educational enterprise.

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Footnotes

[1] 1965 by the Teachers College Press. Permission to use these items is gratefully acknowledged.

[2] Because the purpose of this study was to estimate the effects of the "passage difficulty" variables on examinees' ability to find the main point, it was important to statistically control for the influence of vocabulary. Such control is appropriate in developmental research intended to yield understanding of the characteristics of a domain. After this developmental research has been carried out, it is no longer appropriate to use ANCOVA to analyze test results.

The use of vocabulary as a blocking variable was also considered. However, because of the small number of subjects per cell in this study, including vocabulary as a factor led to a large number of empty cells. Subsequent research might be designed to incorporate vocabulary as a factor, but such an analysis was not possible in the present study.

Table 1

Variables Predicted to Affect the Difficulty of 'Finding the Main Point'

Variable	Values	How used
1. Frequency of statements of main point	High or low	Manipulated
2. Statement of main point	Direct or indirect	Manipulated
3. Fit of passage structure to model reading strategy	Good or poor	Manipulated
4. Non-supportive ideas	Few or many	Manipulated
5. Text cues denoting statement of main point	Present or absent	Constant
6. Text cues denoting details	Present or absent	Constant
7. Vocabulary	Simple or difficult	Constant
8. Syntax	Simple or complex	Constant
9. Structure	Nested or flat	Constant
10. Style	Narrative or argumentative	Constant
11. Passage length	Short or long	Constant
12. Number of main points	Zero, one or more	Constant

Table 2

Characteristics of the Practice Passages

	Frequency of main point statements		Statement of main point		Fit of text structure to model reading strategy		Ideas non-supportive of the main point	
Passage No.	Low	High	Indirect	Direct	Poor	Good	Many	Few
1 ("Easy")		X		X		X		X
2 ("Moderate")	X			X	X			X
3 ("Difficult")	X		X		X		X	

Table 3

Means and Standard Deviations of the Dependent Variables and Covariate

Variable	Possible range	Mean	Standard Deviation
Vocabulary test	0-20	14.95	2.81
Practice passage			
Topic score	0-2	1.80	0.47
Action score	0-2	1.05	0.92
Modifier score	0-2	0.77	0.96
Total score	0-6	3.58[a]	1.56
Experimental passage			
Topic score	0-2	1.27	0.63
Action score	0-2	1.50	0.82
Modifier score	0-2	0.66	0.84
Total score	0-6	3.28[a]	1.57

[a]"Total score" is not equal to the sum of the three component scores because deductions were made for the inclusion of extraneous material in an otherwise correct or partially-correct response.

Table 4

Two-Factor Design Used to Confirm Predicted Passage Difficulty

Difficulty category	Passage	
	Practice	Experimental
Easy	n = 27	n = 5
Moderate	n = 25	n = 6
Difficult	n = 23	n = 6

Appendix

Practice Passages.....40-42

Experimental Passage Classifications.....43

Experimental Passages.....44-59

"Easy"

As time passes, more and more bald eagles are being senselessly killed by humans. So many are being killed that the danger of bald eagles becoming extinct is quickly increasing. We must take steps to prevent our nation's symbol from dying out.

News of their deaths appears very often. Recently in a midwestern state, a man saw a giant American bald eagle circling high in the sky. He was one of those so called sportsmen who kill anything in sight. He quickly stopped his car, aimed, and brought the mighty bird down with one shot. Then he drove off, having made his kill.

Another example occurred in Florida. Two boys found an eagle's nest in a lonely pine. They climbed up to see if there were any eggs in it. There were two. The boys tossed them down to splatter on the ground. The result: two eagles that would never be hatched.

The fact is that acts such as these have made the bald eagle almost extinct. At last count there were fewer than 4000 birds, and the number is getting smaller all the time.

Lots of nonsense is spread about the bald eagle. Some say it is a fierce thief that sweeps down to carry off pets, poultry, and even children. Some think it is a clumsy, cowardly creature that lives by stealing. Both views are wrong, but the views lead to trouble for the bald eagle.

In Wyoming a group of chicken farmers were angry about the loss of a few chickens. They banded together to get the suspected culprit--the bald eagle. Armed with rifles, the group rode into the hills and shot every eagle they could find. Later they learned that a wild dog had stoken the chickens, but it was too late. Twenty-three bald eagles were dead.

Bald eagles are also endangered by mistaken killings and careless acts. If mass murder of the mighty bald eagle does not stop soon, we will lose it forever. We are having our last chance to save the bald eagle.

"Moderate"

Recently in a midwestern state, a man saw a giant American bald eagle circling high in the sky. He was one of those so-called sportsmen who kill anything in sight. He quickly stopped his car, aimed, and brought the mighty bird down with one shot. Then he drove off, having made his kill.

In Florida two boys found an eagle's nest in a lonely pine. They climbed up to see if there were any eggs in it. There were two. The boys tossed them down to splatter on the ground. The result of these stories: one bird dead and two that would never be hatched.

Lots of nonsense is spread about the bald eagle. Some say it is a fierce thief that sweeps down to carry off pets, poultry, and even children. Some think it is a clumsy, cowardly creature that lives by stealing. Both these views are wrong, but some people try to kill eagles because they believe those ideas.

In Wyoming, a group of chicken farmers were angry at the loss of a few chickens. They banded together to get the suspected culprit--the bald eagle. Armed with rifles, the group rode high into the hills and shot every bald eagle they could find. Later they learned that a wild dog had stolen the chickens, but it was too late. Twenty-three bald eagles were dead.

Acts like these, year after year, have made the bald eagle almost extinct. At last count there were fewer than 4,000 of the birds, and the number is getting smaller all the time. We must take steps to prevent the bald eagle from dying out entirely.

Often, bald eagles are killed because of mistakes and carelessness. When young, bald eagles look quite a bit like the golden eagle. Golden eagles are not protected by law like the bald eagle is. Some people have mistakenly killed a bald eagle when they thought they were shooting a golden eagle.

Bald eagles eat mice and rats and other pests. People often use poisons to help get rid of such pests. But if an eagle eats a mouse that has poison in it, then the eagle will also be accidently poisoned.

"Difficult"

Recently in a midwestern state, a forty-two year old ex-businessman saw a giant American bald eagle circling high in the sky. He was one of those so-called sportsmen who kill anything in sight. He quickly stopped his car and pulled out the gun he had recently purchased in a local supermarket. He aimed and brought the mighty bird down with one shot. Then he drove off having made his kill.

Lots of nonsense is spread about the bald eagle. Some say it is a fierce thief that sweeps down to carry off pets, poultry, and even children. Some think it is a clumsy, cowardly creature that lives by stealing. Those are not true beliefs, but some people kill bald eagles anyway. Actually, the eagle is a meat-eating bird that lives on animals.

Killing a bald eagle is prohibited by law, but too many people are willing to risk the $500 fine. Of course there are always the gun-happy hunters and those who are simply careless.

The bald eagle is one of the largest birds we have. Its wings can reach seven feet across, and it may weigh up to ten pounds. An eagle can dive at 60 miles an hour; in fact, some eagles have been clocked at an astounding 100 miles an hour. The eye sight of an eagle is outstanding; one was once seen diving for a fish floating on a lake a full three miles away.

Each year, the national park system makes an effort to count the number of bald eagles living in the United States. In 1962, roughly 6,000 birds were counted by the park system employees. In 1968, the count was even less than 4,000 birds. Park rangers fear the count may never stop decreasing.

The bald eagle is a beautiful and mighty bird. Perhaps that is why the founders of our country chose it to be the national symbol. Its image can be seen on money, like the quarter or the one dollar bill, and is even found on the seal of the President of the United States. Some indians used to wear its feathers to show acts of bravery like soldiers wear medals today.

Experimental Passage Classifications

Passage version	Frequency of main point statements		Statement of main point		Fit of text structure to model reading strategy		Ideas non-supportive of the main point	
	Low	High	Indirect	Direct	Poor	Good	Many	Few
A		X		X		X		X
B	X			X		X		X
C		X		X	X			X
D	X			X	X			X
E		X		X		X	X	
F	X			X		X	X	
G		X		X	X		X	
H	X			X	X		X	
I		X	X			X		X
J	X		X			X		X
K		X	X		X			X
L	X		X		X			X
M		X	X			X	X	
N	X		X			X	X	
O		X	X		X		X	
P	X		X		X		X	

A

One of the most difficult of all bridge-building feats was accomplished twenty years ago when a bridge called "Big Mac" was constructed in northern Michigan. The task was so difficult that most people had said that the bridge could not be built. But hundreds of people worked hard for several years, and eventually the bridge was completed.

A big problem was that the bridge had to be built over a strip of water that is both very deep and very wide. The strip of water, called the Straits of Mackinac, separates Lake Michigan from Lake Huron and also divides the state of Michigan into two parts. In some places the water is almost 400 feet deep, and the two parts of the state lie almost four miles apart.

Another problem was that the winds that blow through the straits are very strong. It is not uncommon for wind speeds to reach 75 miles per hour, especially during the winter season. Many people said that no bridge would be strong enough to withstand the strong winds.

Large waves were also a concern to the bridge builders. When the winds are blowing the strongest, the waves on the top of the water can become quite big. At one time so many boats were being damaged by the waves that the United States Coast Guard was forced to forbid all pleasure-boating on the Straits except when the water and the wind were both calm.

During part of the year, winter builds its own bridge between the two parts of Michigan. This bridge, however, is not safe enough for vehicles to cross over. It is made out of ice. With winters as fierce as they are in northern Michigan, the grinding ice could possibly damage the bridge.

Still, engineers began to work on the many problems. They decided that the difficult job could be done. They would build a suspension bridge. (This is a bridge in which the roadway is hung, or suspended, from great cables. The cables are supported by tall towers.) The bridge would be five miles long, and the suspension parts would be the longest ever built.

People also said a bridge would cost too much--one hundred million dollars. How would the state pay for it? It was decided that money would be raised by selling bonds. The bond buyers would be paid back by all who used the bridge. Cars, trucks, and buses would pay a toll when they crossed the bridge.

In order to build the bridge, the engineers determined that thirty-four underwater supports, called caissons, would have to be sunk down through the water and mud to solid rock. Each had to be placed within less than an inch of the right spot. Otherwise, the steel parts being made elsewhere would not fit. The job would be tricky, but they said they could do it.

So they went to work. Parts of the bridge were built in mills and shops all across the country. The pieces of the bridge were shipped to the Straits to be put together. They came on railroad cars, on barges towed by tugs, and on large ships.

The caissons were put in first. Next the steel cable towers, tall as fifty story buildings were built. Then the two cables that would support the road were spun. A total of 12,580 wires had to be squeezed into each round cable to make them strong enough. The cables were put in place, huge steel frames were hung from the cables, and the roadway was built.

On Labor Day, 1957, "Big Mac" was officially opened to traffic. The bridge that many thought would never be built had been built. All the many problems that made building the bridge so difficult had been solved.

B

One of the most difficult of all bridge-building feats was accomplished twenty years ago when a bridge called "Big Mac" was constructed in northern Michigan. The task was so difficult that most people had said that the bridge could never be built. But hundreds of people worked hard for several years, and eventually the bridge was completed.

The bridge had to be built over a strip of water that is both very deep and very wide. The strip of water, called the Straits of Mackinac, separates Lake Michigan from Lake Huron and also divides the state of Michigan into two parts. In some places the water is almost 400 feet deep, and the two parts of the state lie almost four miles apart.

The winds that blow through the Straits are very, very strong. It is not uncommon for wind speeds to reach 75 miles per hour, especially during the winter season. Many people said that no bridge would be strong enough to withstand the strong winds.

Large waves were a concern to the bridge builders. When the winds are blowing the strongest, the waves on the top of the water can become quite big. At one time so many boats were being damaged by the waves that the United States Coast Guard was forced to forbid all pleasure-boating on the Straits except when the water and the wind were both calm.

During part of the year, winter builds its own bridge between the two parts of Michigan. This bridge, however, is not safe enough for vehicles to cross over. It is made out of ice. With winters as fierce as they are in northern Michigan, the grinding ice could possibly damage a bridge.

The engineers assigned to study the possibility of building the bridge decided they would build a suspension bridge. (This is a bridge in which the roadway is hung, or suspended, from great cables. The cables are supported by tall towers.) The bridge would be five miles long, and the suspension parts would be the longest ever built.

People said a bridge would cost too much--one hundred million dollars. How would the state pay for it? It was decided that money would be raised by selling bonds. The bond buyers would be paid back by all who used the bridge. Cars, trucks, and buses would pay a toll when they crossed the bridge.

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So they went to work. Parts of the bridge were built in mills and shops all across the country. The pieces of the bridge were shipped to the Straits to be put together. They came on railroad cars, on barges towed by tugs, and on large ships.

The caissons were put in first. Next the steel cable towers, tall as fifty story buildings, were built. Then the two giant cables that would support the road were spun. A total of 12,580 wires had to be squeezed into each round cable to make them strong enough. The cables were put in place, huge steel frames were hung from the cables, and the roadway was built.

On Labor Day, 1957, "Bic Mac" was officially opened to traffic. Today cars, trucks, and buses can cross the bridge in ten minutes.

C

Between the towns of Macknaw City and St. Ignace in Michigan lies a strip of water called the Straits of Mackinac. It separates Lake Michigan from Lake Huron and also divides the state of Michigan into two parts. In some places the water is almost 400 feet deep, and the two parts of the state lie almost four miles apart.

A major problem through there is that the winds are very, very strong. It is not uncommon for wind speeds to reach 75 miles per hour, especially during the winter season. Many people said that a bridge built across the Straits would not be strong enough to withstand the strong winds.

Large waves can also be a problem in the Straits of Mackinac. When the winds are blowing the strongest, the waves on the top of the water can become quite big. At one time so many boats were being damaged by the waves that the United States Coast Guard was forced to forbid all pleasure-boating on the Straits except when the water and the wind were both calm.

When a bridge nicknamed "Big Mac" was constructed across the Straits twenty years ago, one of the most difficult of all bridge-building feats was accomplished. The task was so difficult that most people had said that the bridge could never be built. But hundreds of people worked hard for several years, and eventually the bridge was completed.

During part of the year, winter builds its own bridge between the two parts of Michigan. This bridge, however, is not safe enough for vehicles to cross over. It is made out of ice. With winters as fierce as they are in northern Michigan, the grinding ice could possibly damage a bridge.

The engineers assigned to study the possibility of building the bridge decided that they would build a suspension bridge. (This is a bridge in which the roadway is hung, or suspended, from great cables. The cables are supported by tall towers.) The bridge would be five miles long, and the suspension parts would be the longest ever built. There were many problems to deal with in building this bridge, but the engineers decided that the difficult job could be done.

People also said a bridge would cost too much--one hundred million dollars. How would the state pay for it? It was decided that money would be raised by selling bonds. The bond buyers would be paid back by all who used the bridge. Cars, trucks, and buses would pay a toll when they crossed the bridge.

In order to build the bridge, the engineers determined that thirty-four underwater supports, called caissons, would have to be sunk down through the water and mud to solid rock. Each had to be placed within less than an inch of the right spot. Otherwise the steel parts being made elsewhere would not fit. The job would be tricky, but they said they could do it.

On Labor Day, 1957, "Big Mac" was officially opened to traffic. The bridge that many thought could never be built had been built. All the many problems that made building the bridge so difficult had been solved.

Parts of the bridge were built in mills and shops all across the country. The pieces of the bridge were shipped to the Straits to be put together. They came on railroad cars, on barges towed by tugs, and on large ships.

The caissons were put in first. Next the steel cable towers, tall as fifty story buildings, were built. Then the two giant cables that would support the road were spun. A total of 12,580 wires had to be squeezed into each round cable to make them strong enough. The cables were put in place, huge steel frames were hung from the cables, and the roadway was built.

D

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The winds through the Straits of Mackinac are very, very strong. It is not uncommon for wind speeds to reach 75 miles per hour, especially during the winter season. Many people said that a bridge built across the Straits would not be strong enough to withstand the strong winds.

Large waves can be a problem in the Straits of Mackinac. When the winds are blowing the strongest, the waves on the top of the water can become quite big. At one time so many boats were being damaged by the waves that the United States Coast Guard was forced to forbid all pleasure-boating on the Straits except when the water and the wind were both calm.

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On Labor Day, 1957, "Big Mac" was officially opened to traffic. Today cars, trucks, and buses can cross the bridge in ten minutes.

Parts of the bridge were built in mills and shops all across the country. The pieces of the bridge were shipped to the Straits to be put together. They came on railroad cars, on barges towed by tugs, and on large ships.

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E

One of the most difficult of all bridge-building feats was accomplished twenty years ago when a bridge called "Big Mac" was constructed in northern Michigan. The task was so difficult that most people had said that the bridge could never be built.

A big problem was that the bridge had to be built over a strip of water that is both very deep and very wide. The strip of water, called the Straits of Mackinac, separates Lake Michigan from Lake Huron, two of the five Great Lakes, all of which are located on the northern border of the continental United States. It also divides the state of Michigan into two parts. These parts are called the Upper and Lower Peninsulas. In some places the water is almost 400 feet deep, and the two parts of the state lie almost four miles apart.

Another big problem was that the winds that blow through the Straits are very strong. It is not uncommon for wind speeds to reach 75 miles per hour, especially during the cold winter season. Michigan's winters are the fifth coldest of all states, with an average seasonal snowfall of 172 inches. Many people said that no bridge would be strong enough to withstand the strong winds.

Large waves were also a concern to the bridge builders. When the winds are blowing the strongest, the waves on the top of the water can become quite big. At one time so many boats were being damaged by the waves that the United States Coast Guard was forced to forbid all pleasure-boating on the Straits except when the water and the wind were both calm.

Each day members of the Coast Guard constantly monitor weather conditions. They inform boaters whether or not it is safe to go out on the Straits. Weather forecasts and Coast Guard recommendations are announced over the radio every half hour. Different colored flags are raised over the Coast Guard stations to signal specific weather conditions to the boaters.

The engineers assigned to work on a bridge that would cross the Straits began to work on the many problems. They decided that the difficult job could be done. They would build a suspension bridge. (This is a bridge in which the roadway is hung, or suspended, from great cables. The cables are supported by tall towers.) The bridge would be five miles long, and the suspension parts would be the longest ever built.

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In order to build the bridge, the engineers determined that thirty-four underwater supports, called caissons, would have to be sunk down through the water and mud to solid rock. Each had to be placed within less than an inch of the right spot. Otherwise, the steel parts being made elsehwere would not fit. The job would be tricky.

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During part of the year, winter builds its own bridge between the two parts of Michigan. This bridge, however, is not safe enough for vehicles to cross over. It is made out of ice. With winters as fierce as they are in northern Michigan, the grinding ice could possibly damage a bridge.

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The builders went to work. Parts of the bridge were built in mills and shops all across the country. No stone or brick was to be used in the bridge. Bridges of years ago were exclusively made of such materials. The pieces of the bridge were shipped to the Straits to be put together.

The caissons were put in first. Next the steel cable towers, tall as fifty story buildings, were built. Then the two giant cables that would support the road were spun. A total of 12,580 wires had to be squeezed into each round cable to make them strong enough. The cables were so strong they could hold enough two-ton trucks to make a line 150 miles long. The cables were put in place, huge steel frames were hung from the cables, and the roadway was built.

On Labor Day, 1957, "Big Mac" was officially opened to traffic. 60
Today cars, trucks, and buses can cross the bridge in ten minutes.

Between the towns of Mackinaw City and St. Ignace in Michigan lies a strip of water called the Straits of Mackinac. It separates Lake Michigan from Lake Huron, two of the five Great Lakes, all of which are located on the northern border of the continental United States. It also divides the state of Michigan into two parts. These parts are called the Upper and Lower Peninsulas. In some places the water is almost 400 feet deep, and the two parts of the state lie almost four miles apart.

A major problem through there is that the winds are very, very strong. It is not uncommon for wind speeds to reach 75 miles per hour, especially during the cold winter season. Michigan's winters are the fifth coldest of all states, with an average seasonal snowfall of 172 inches. Many people said that a bridge built across the Straits would not be strong enough to withstand the strong winds.

Large waves can also be a problem in the Straits of Mackinac. When the winds are blowing the strongest, the waves on the top of the water can become quite big. At one time so many boats were being damaged by the waves that the United States Coast Guard was forced to forbid all pleasure-boating on the Straits except when the water and the wind were both calm.

Each day members of the Coast Guard constantly monitor weather conditions. They inform boaters whether or not it is safe to go out on the Straits. Weather forecasts and Coast Guard recommendations are announced over the radio every half hour. Different colored flags are raised over the Coast Guard stations to signal specific weather conditions to the boaters.

In the early 1940s, lots of time, effort, and money were invested to build a bridge over a similar body of water near Tacoma, Washington. Many had claimed it would require a miracle for workers to build a bridge across the Tacoma Narrows. They said the job was too dangerous and would be too difficult. But workers went ahead. After years of difficult struggle, the bridge was actually completed. But soon the bridge collapsed. A strong Tacoma Narrows Bridge could not be built. Only a few years later a similar effort was being considered across the Straits of Mackinac. Would this effort produce another Tacoma Narrows Bridge?

The engineers assigned to study the possibility of building the bridge decided they would build a suspension bridge. (This is a bridge in which the roadway is hung, or suspended, from great cables. The cables are supported by tall towers.) The bridge would be five miles long, and the suspension parts would be the longest ever built. The builders of the Tacoma Narrows Bridge would probably have shuddered with fear if faced with building a bridge across the Straits of Mackinac.

People also said a bridge would cost too much--one hundred million dollars. How would the state pay for it? It was decided that money would be raised by selling bonds. The bond buyers would be paid back by all who used the bridge. Cars, trucks, and buses would pay a toll when they crossed the bridge.

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Many people had compared the task of building a bridge across the Straits of Mackinac to the earlier task of building the Tacoma Narrows Bridge in Washington. The Tacoma Narrows Bridge was to stand only a short time; "Big Mac" is yet strong and in continual use a full twenty years after it was officially opened to traffic.

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